NASA Earth Sciences:
Earth Understandings for Human Needs

Dr. Peter Hildebrand, Director
NASA/Goddard Earth Sciences Division

NASA Earth Science

What governs Earth's climate?

How is Earth's climate changing?

How will climate changes affect life on earth?

Need for Satellite-Based Observations

- Ground-based measurements of climate:
  - are insufficient and declining
    - > Particularly outside N. America and Europe
  - lack the uniform calibration needed to assess climate variability and change

- Satellite-based observations of Earth's global climate:
  - provide uniform global coverage
  - can be calibrated against validating measurements
    - > Ground and airborne
  - explain climate change forcing:
    - > Radiation, Aerosols, Atmospheric chemistry, Global ocean circulation, Clouds explain climate change impacts:
    - > Sea level rise, Ozone depletion, Sea ice depletion, Ice sheet melt, Mountain glacier melt, Air quality, Polar bear habitat, Longer growing season in high latitudes and on high mountains

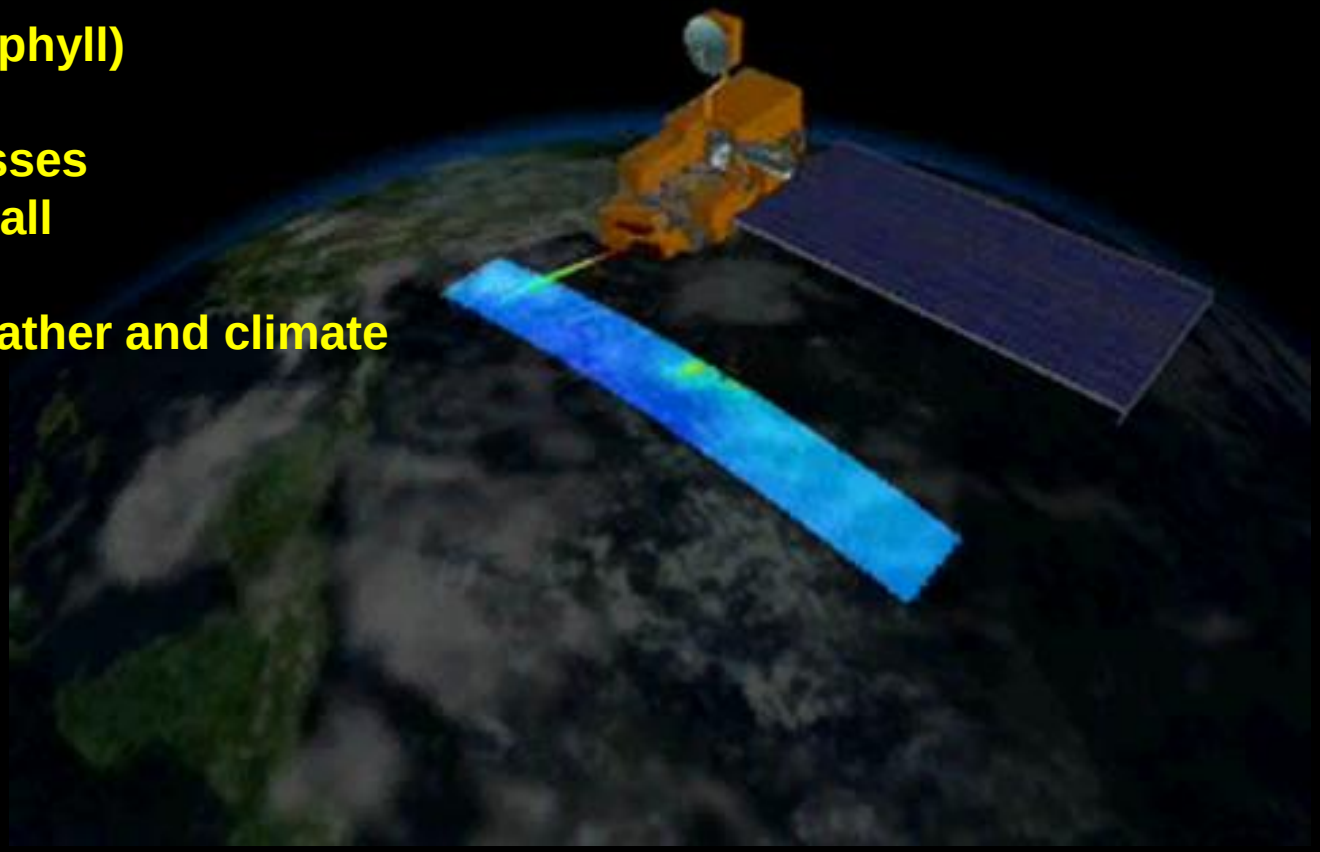
Satellite measurement of Earth properties

Multiple satellites measure a wide variety of earth processes:
winds, temperatures, clouds, pollution, the ocean and land surface.

Data are used for weather and climate predictions

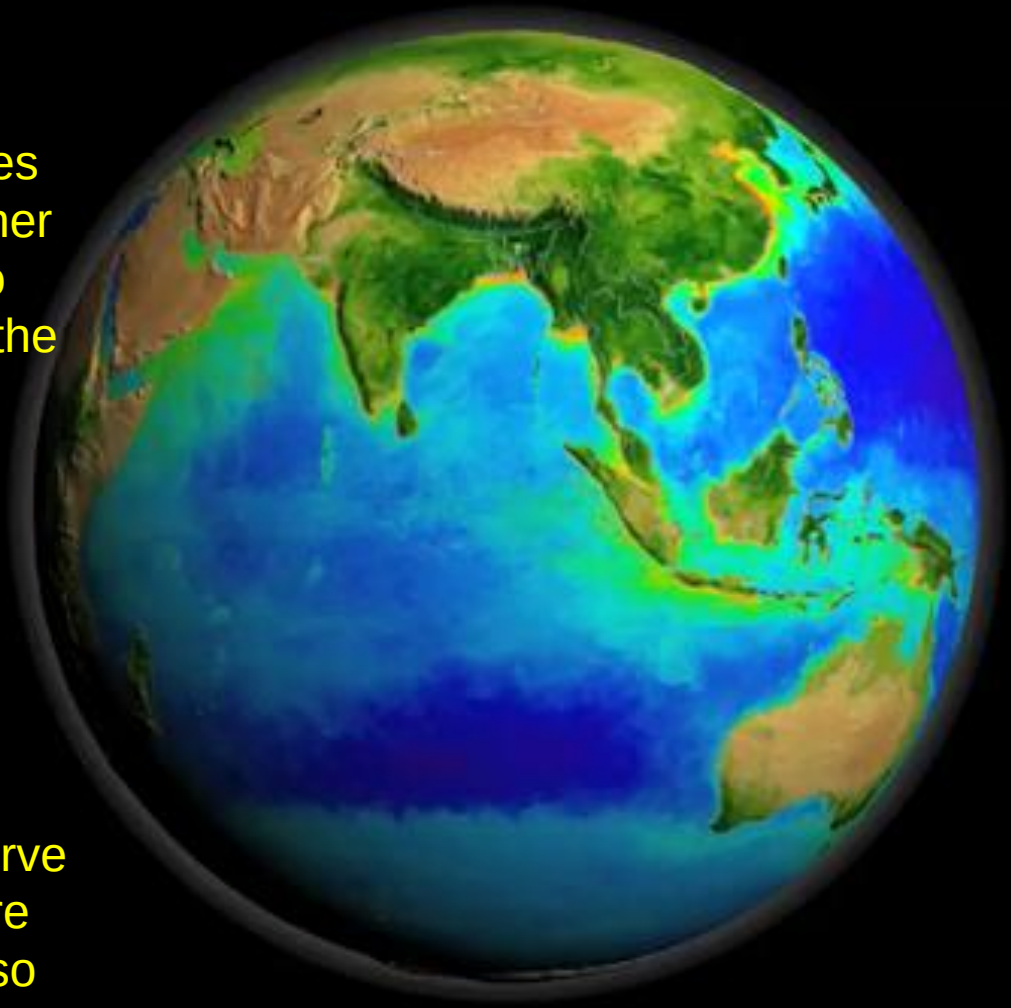
Satellite measurement of Earth properties

- **Cross-track scanners measure:**
  - **Surface temperature (land and sea)**
  - **Atmospheric temperature and humidity**
  - **Plant life (chlorophyll)**
  - **Ocean winds**
  - **Atmospheric gasses**
  - **Clouds and rainfall**
  - **… and lots more**
- **Data are used for weather and climate predictions**



Satellite measurement of Earth properties

Data from satellites are stitched together in a computer to make a picture of the whole Earth.

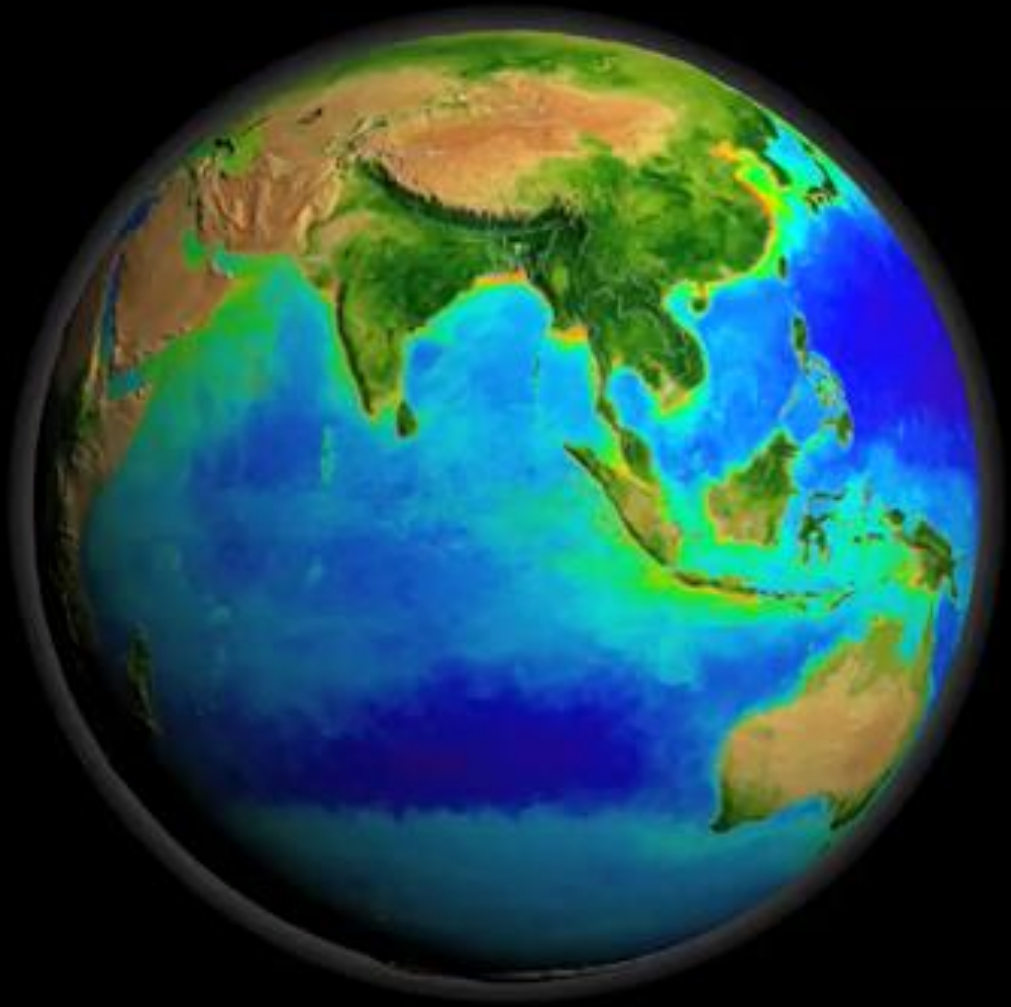


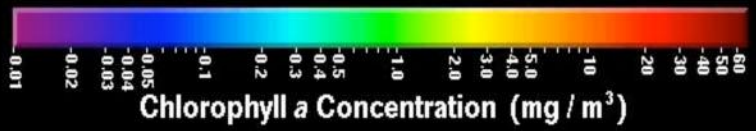
NASA satellite data are used worldwide to better understand the Earth and how it operates.

The satellites observe the full Earth more than once a day so we can measure night and day-time events.

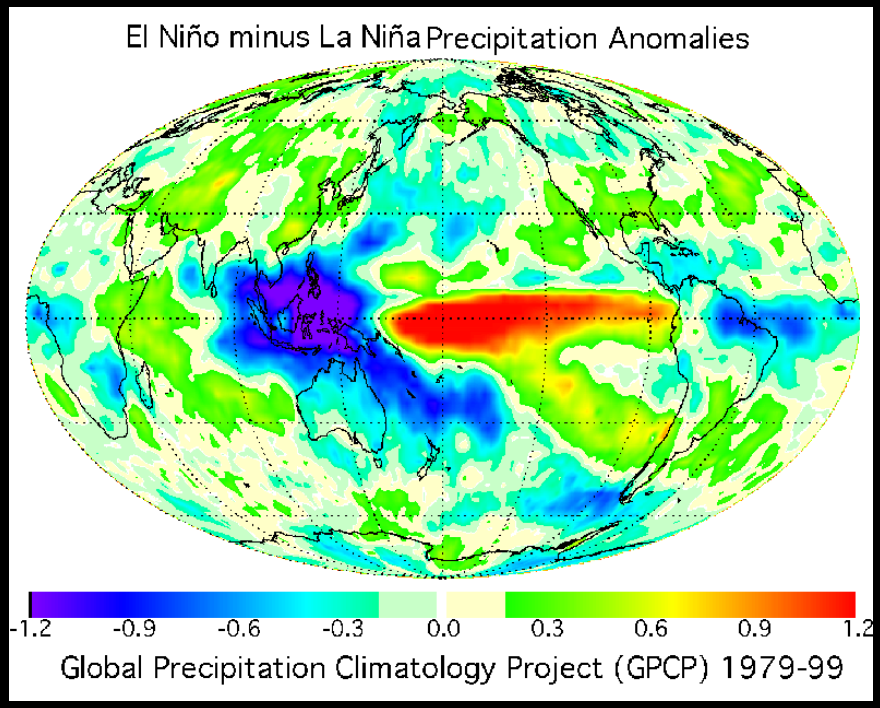
We support the NOAA weather service and many other Agencies with our Earth observations.

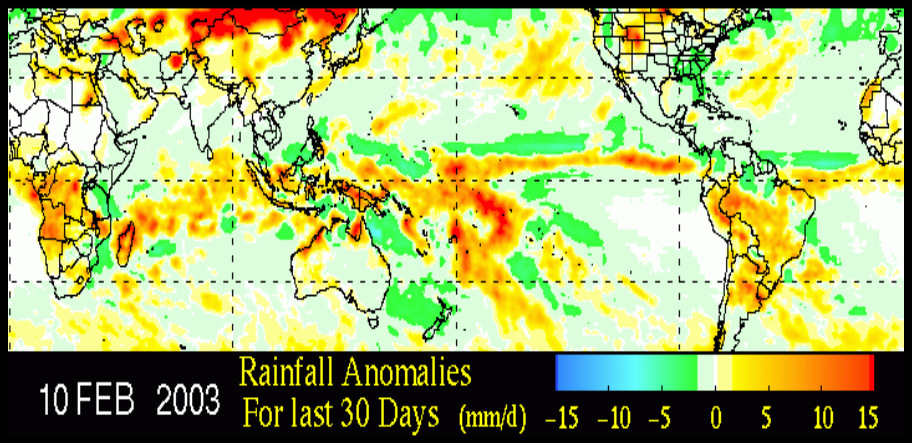
Satellite measurement of Earth biological properties





Global Precipitation Measurement: TRMM → GPM



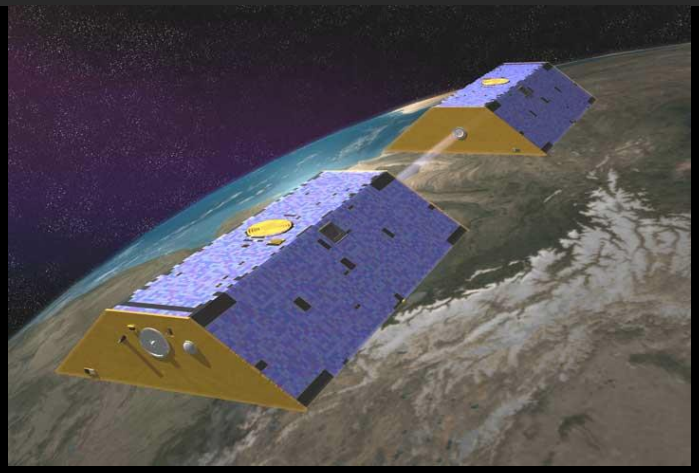


- **Global precipitation measurement with TRMM: a great leap forward!**
  - **Quasi-operational measurement of *global* precipitation (with other satellites)**
    - **10 -- 85 GHz radiometers** (with other satellites)
    - **13.6 GHz precipitation radar**
    - **Global coverage** (with other satellites)
    - **Resolution: variable**
  - **Measure linkages: climate – weather – water cycle – ocean circulation**

- **Needed improvements:**
  - **Better accuracy**
  - **Improved spatial-temporal sampling**
  - **Improved vertical resolution**
  - **High latitude precipitation & snow**

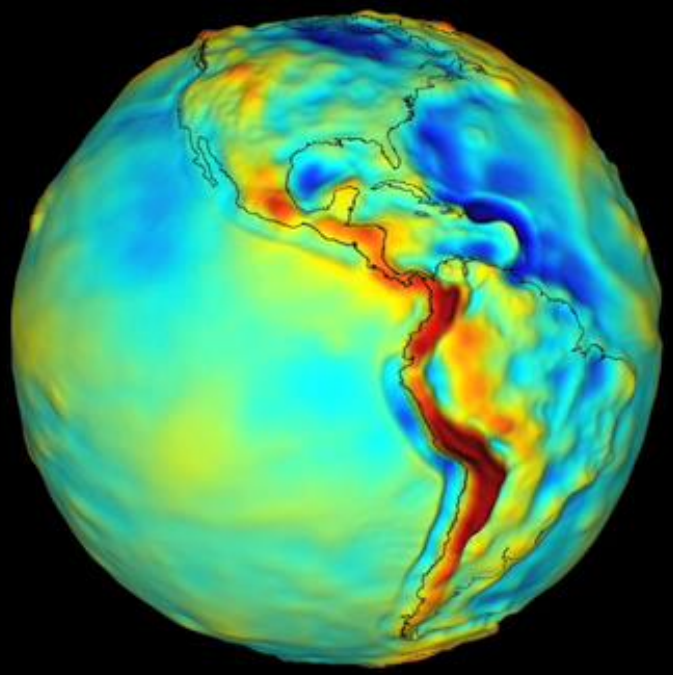
***Tropical Rainfall Measuring Mission: http://trmm.gsfc.nasa.gov/**

NASA GRACE*
Gravity Recovery and Climate Experiment



The Gravity Recovery and Climate Experiment measures the Earth gravity field using a pair of satellites.

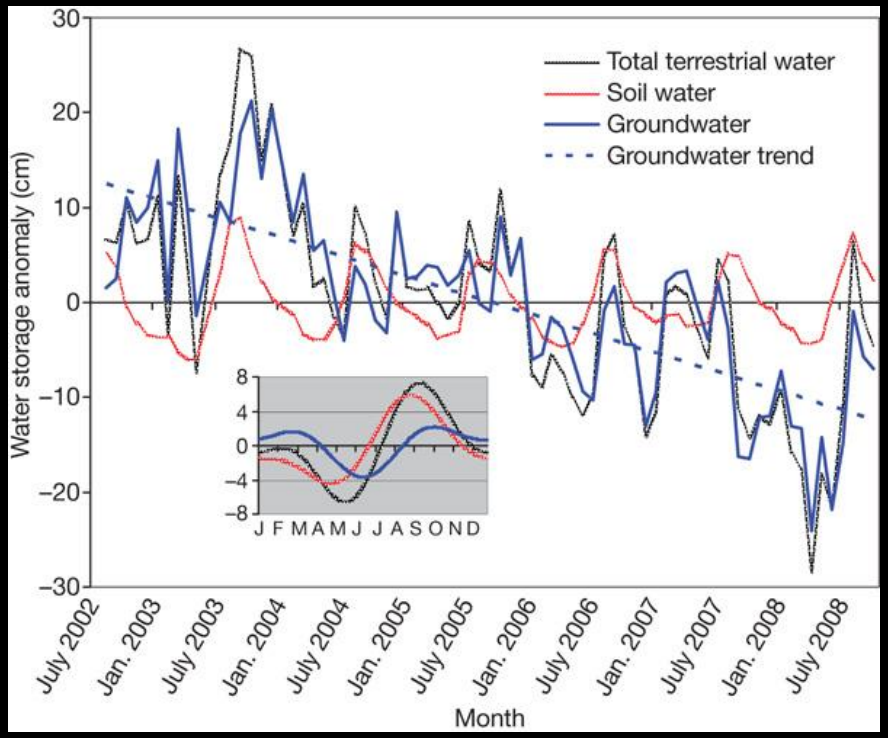
Earth's gravity field = geology + oceans + ice sheets + soil moisture + ground water + ...

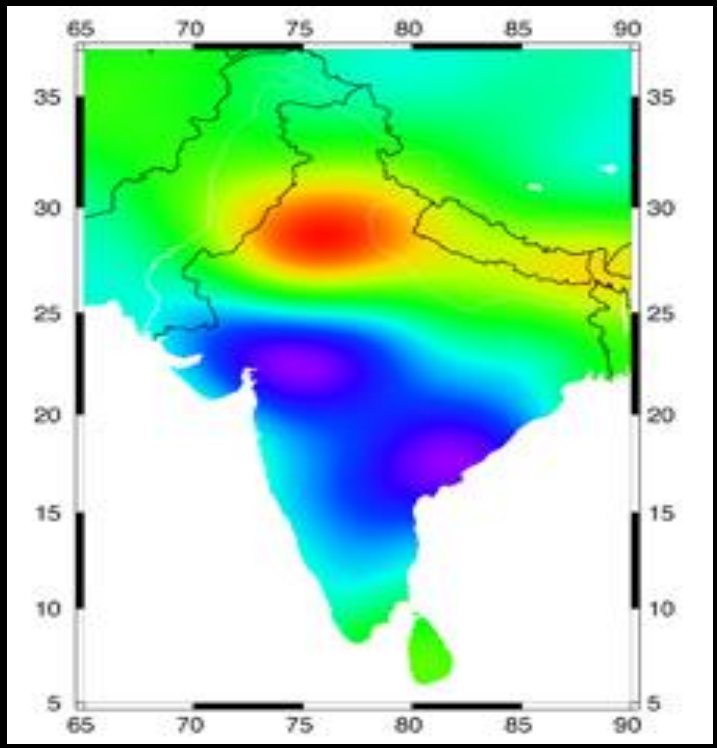


*** GRACE is a joint partnership between NASA and DLR in Germany.**

NASA GRACE*
Gravity Recovery and Climate Experiment

India's Disappearing Groundwater: observations by GRACE show regions that are losing centimeters of groundwater each year.



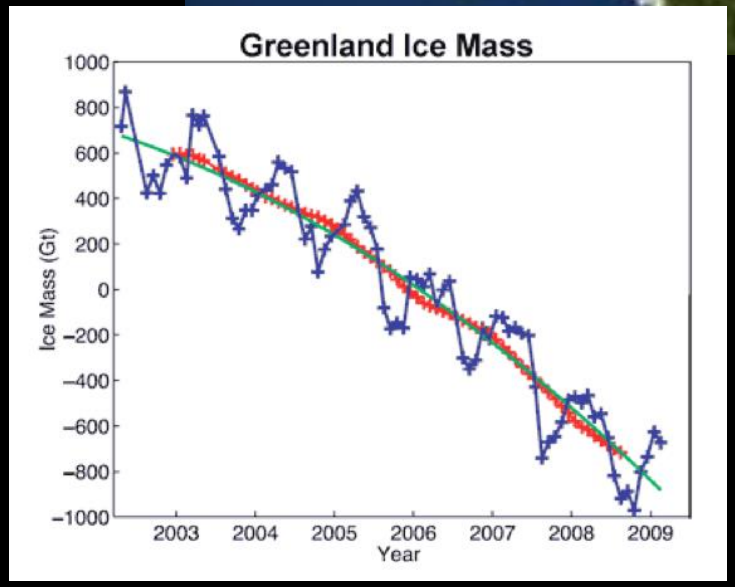


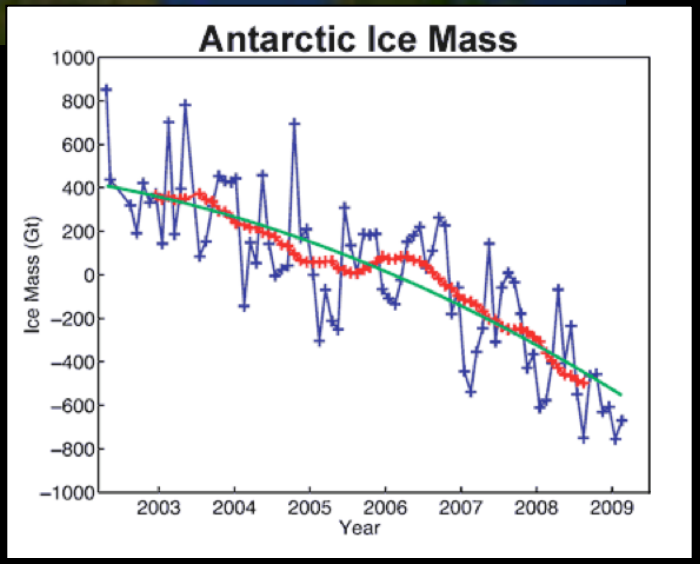
Monthly time series of anomalies of GRACE-derived total TWS, modeled soil-water storage and estimated groundwater storage, averaged over Rajasthan, Punjab and Haryana, plotted as equivalent heights of water in centimeters. Also shown is the best-fit linear groundwater trend. Inset, mean seasonal cycle of each variable. Credit: M. Rodell et al., Satellite-Based Estimates of Groundwater Depletion in India, Nature 460, August 2009

***Joint with DLR, Germany**

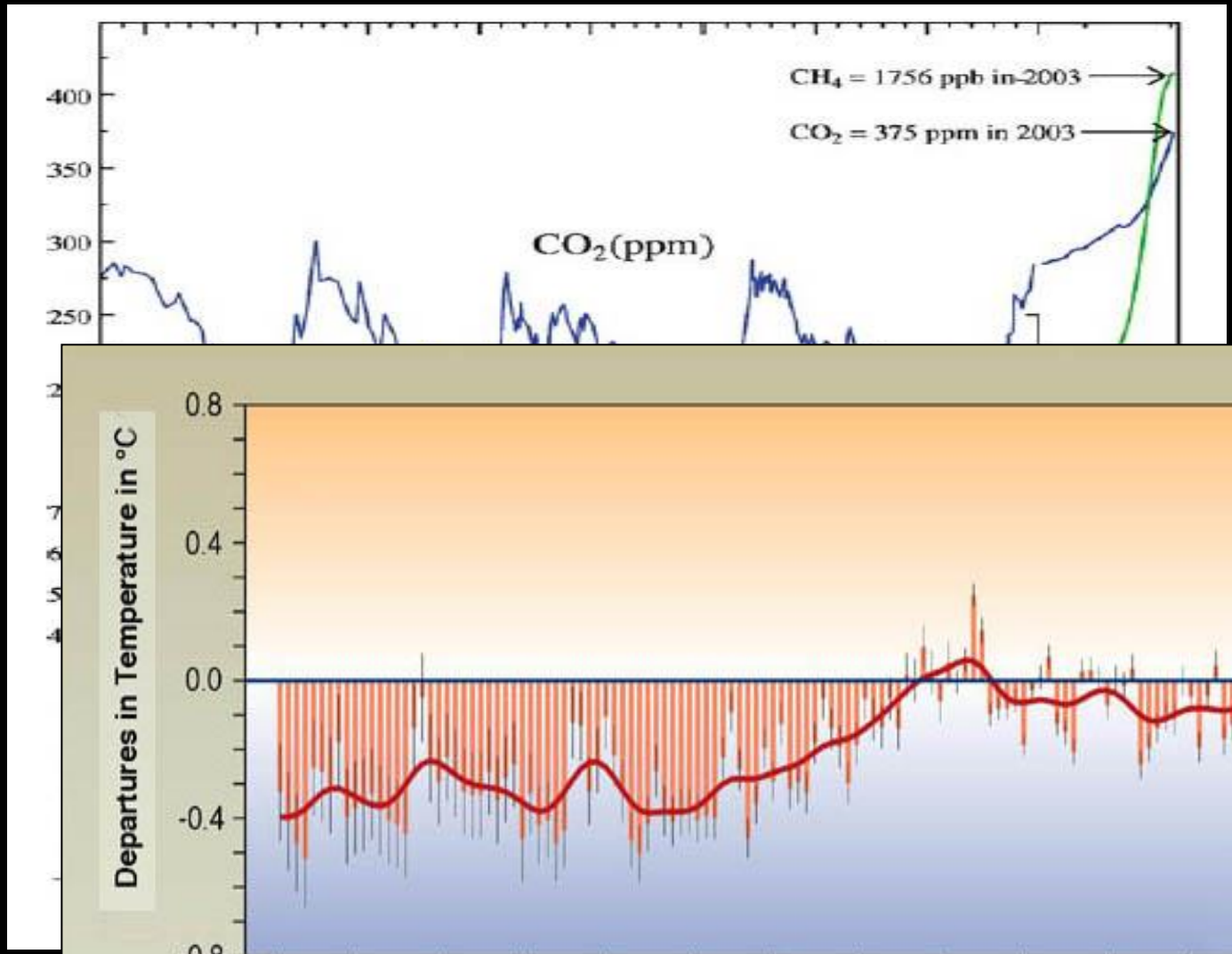
Polar Ice


7
6
5
4
3
million km² sea ice
1979
2007
2010
1980
1985
1990
1995
2000
2005
2010


Greenland Ice Mass
Ice Mass (Gt)
1000
800
600
400
200
0
−200
−400
−600
−800
−1000
2003
2004
2005
2006
2007
2008
2009
Year


Antarctic Ice Mass
Ice Mass (Gt)
1000
800
600
400
200
0
−200
−400
−600
−800
−1000
2003
2004
2005
2006
2007
2008
2009
Year

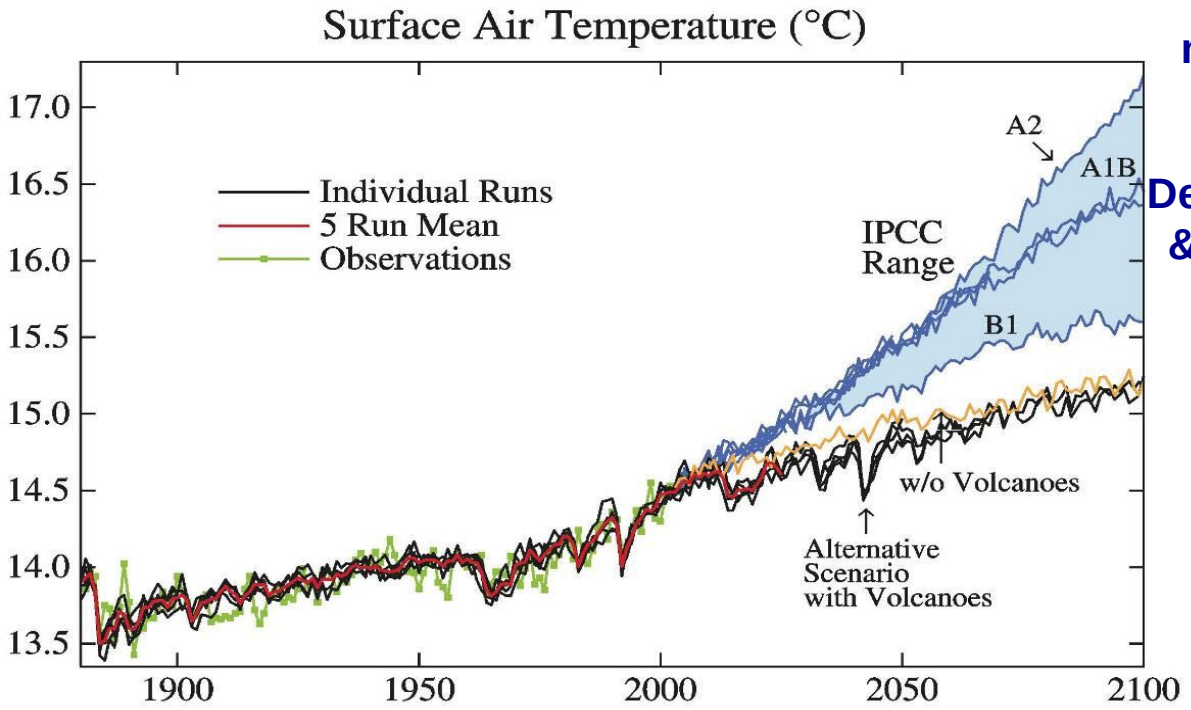
Global Climate and Climate Change



Humans are Changing the Earth

Climate Forecasting

Global Climate Simulations



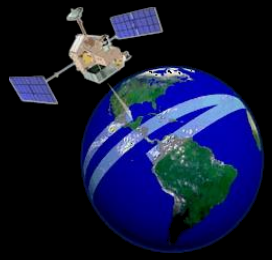
Climate Simulations for IPCC 2007 Report

- GISS Model Fits Observations Well for 1880-2003
  (but trade-off between sensitivity & forcing)
- Future Global Warming Depends Strongly on GHG Scenarios
  (but also depends on uncertain aerosol forcing)

NASA Earth Science

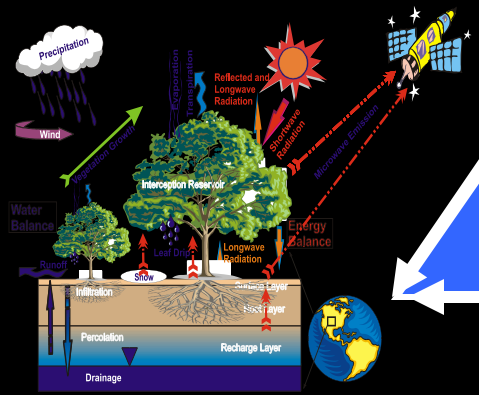
1. Observations

Space Missions:
EOS->NPOESS,
Hydros/SMAP,
GRACE,TRMM/GPM,
CLPP/SCLP,
WaTeR/SWOT



Field Programs:
SGP/SMEX, CLPX

2. Modeling and Data Assimilation

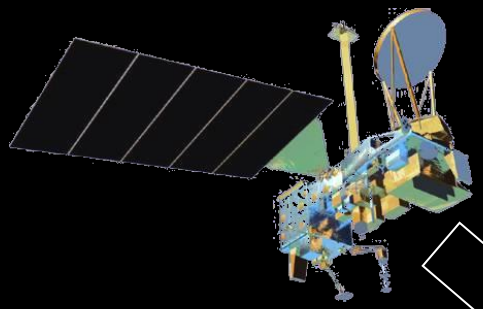


LIS/GLDAS/NLDAS, GMAO,
NOAA/NASA/DoD JCSDA

3. Applications

Water Management: EPA, BoR, NWS
Security: DHS, USAF, Army, USAID,
Fire warnings

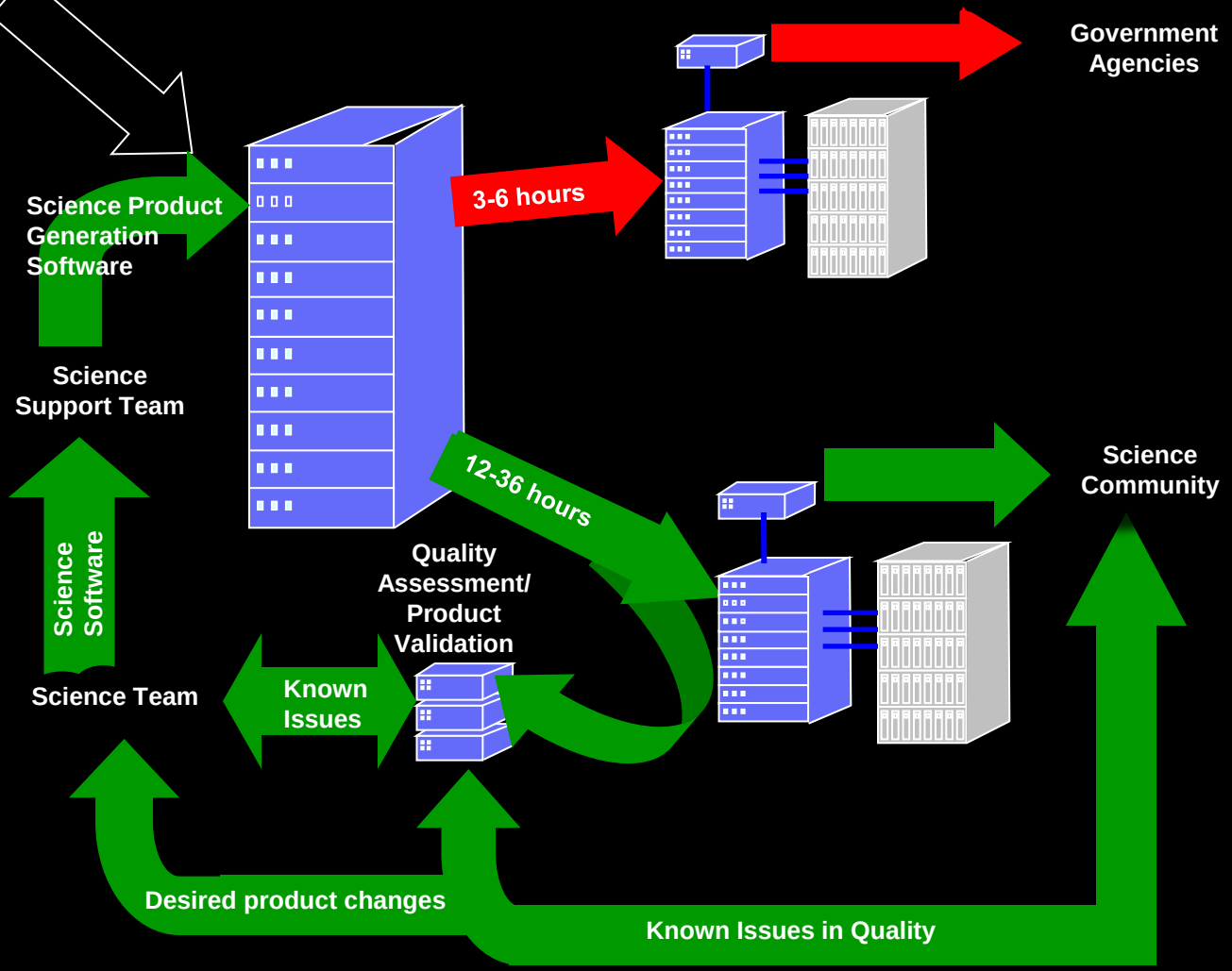
Data Systems in Earth Science Research and Applications



Long-term science data sets are created from Earth imaging instruments.

Data are calibrated and quality assessed to ensure science data quality.

Focus is on stability, precision, accuracy, and characterization of errors.

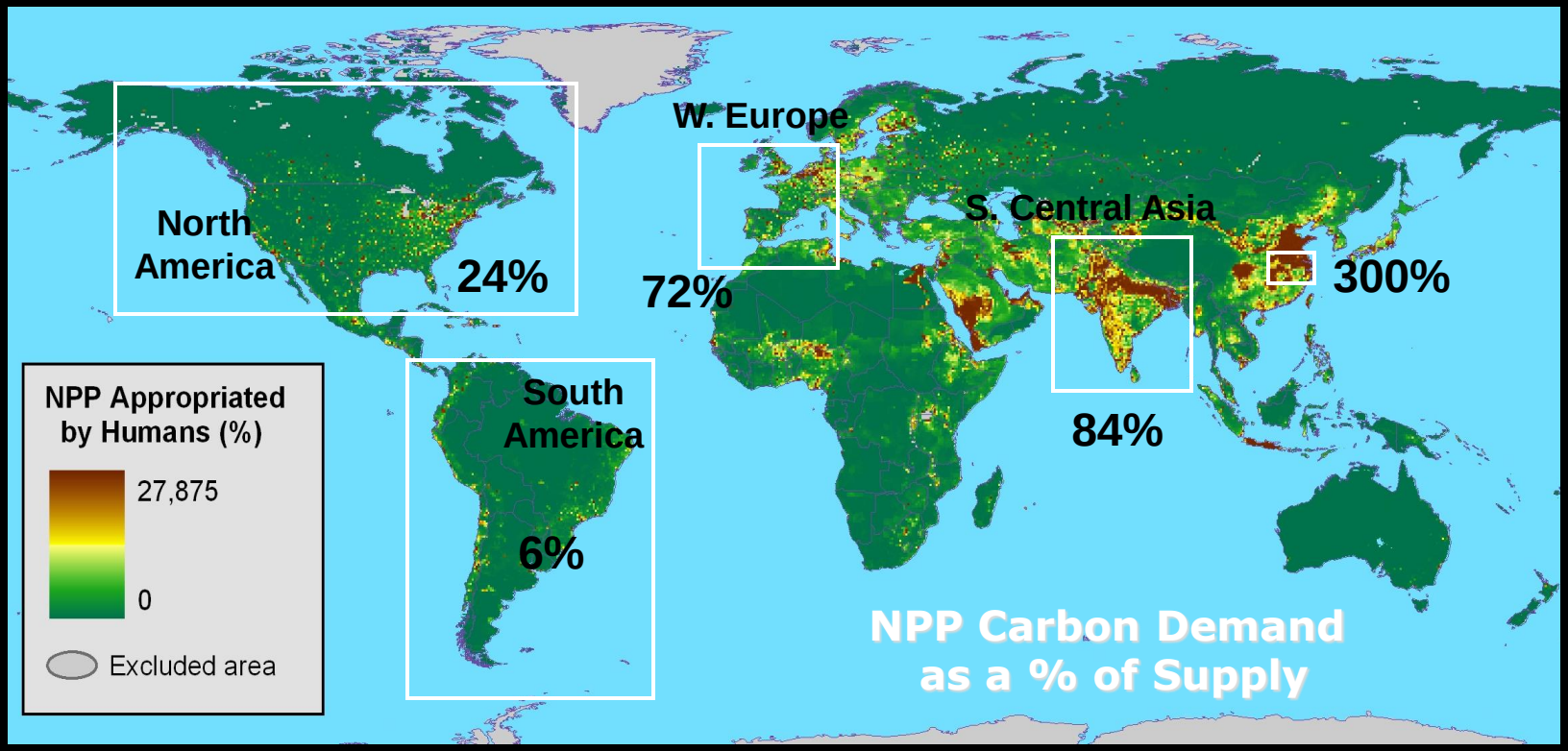


Global Patterns in Human Consumption of Net Primary Production (NPP)

Global NPP Demand is 11.5 Pg C per year (20% of Supply)

There are large regional and local variations

6% (South America) to over 70% (Europe and Asia), and from near 0% (Central Australia) to over 30,000% (New York City, Bejing).



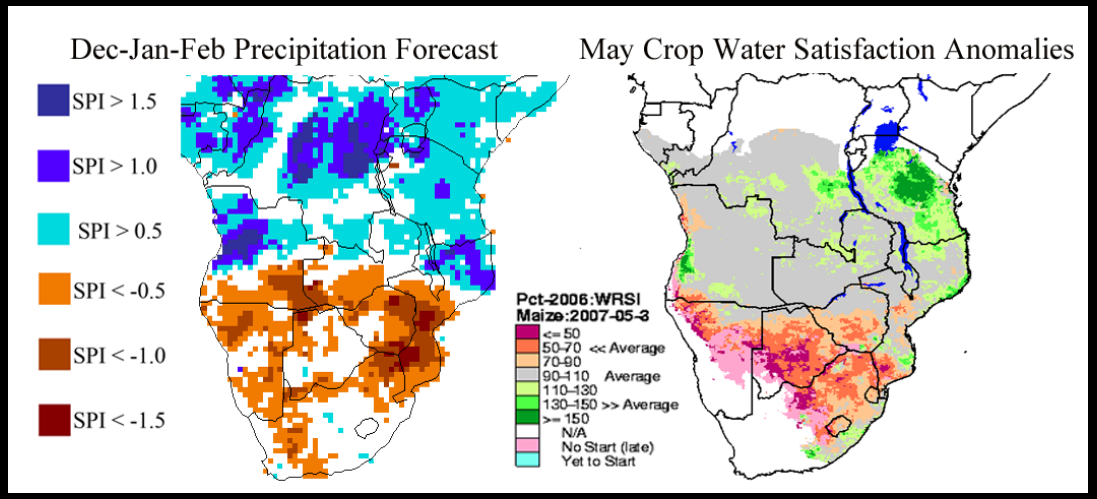
The rate at which humans consume NPP-C is a powerful aggregate measure of human impact on biosphere function.

M. L. Imhoff, et al. **Nature**, 24 June 2004

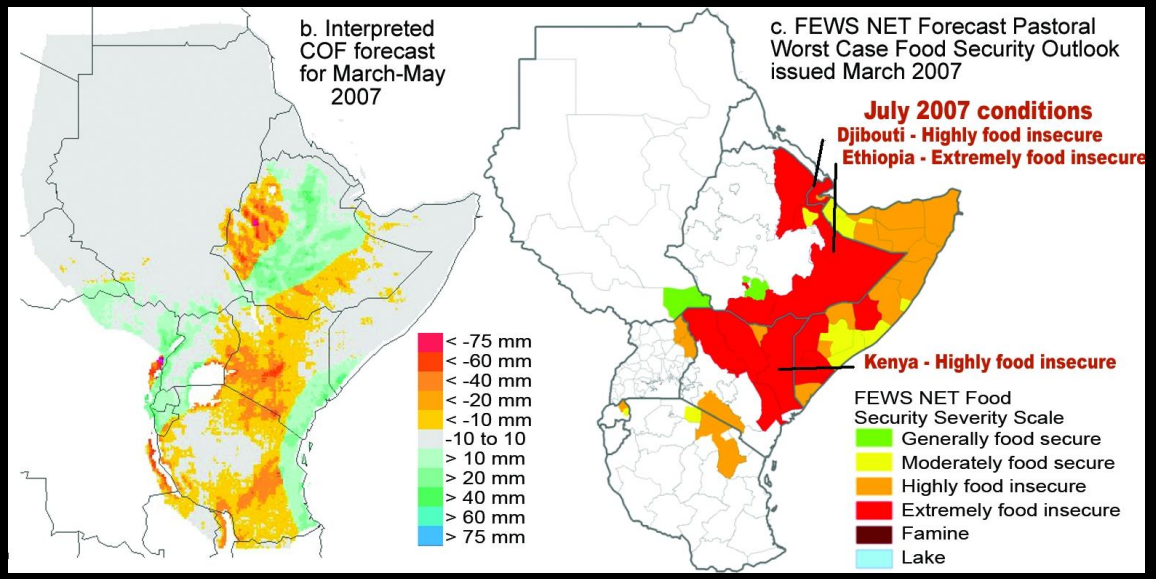
GSFC Biospheric Sciences Branch

Famine Warnings Using Remote Sensing and Models

Early famine warnings by the **Famine Early Warning System Network*** use biophysical satellite remote sensing, coupled with climate, ecosystem, crop and economic models.

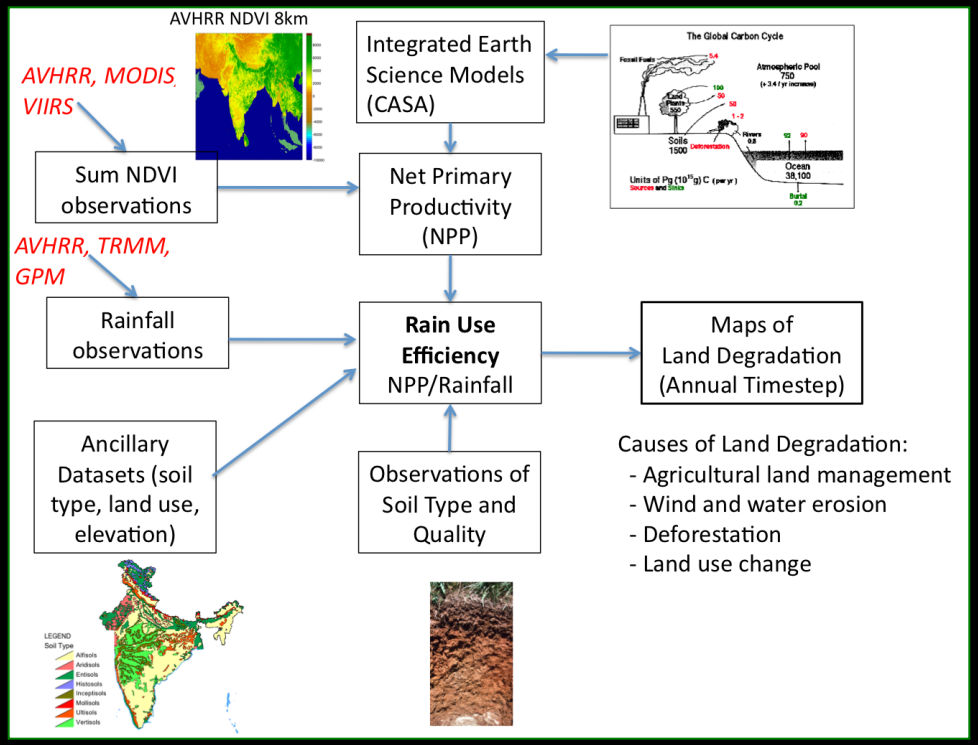


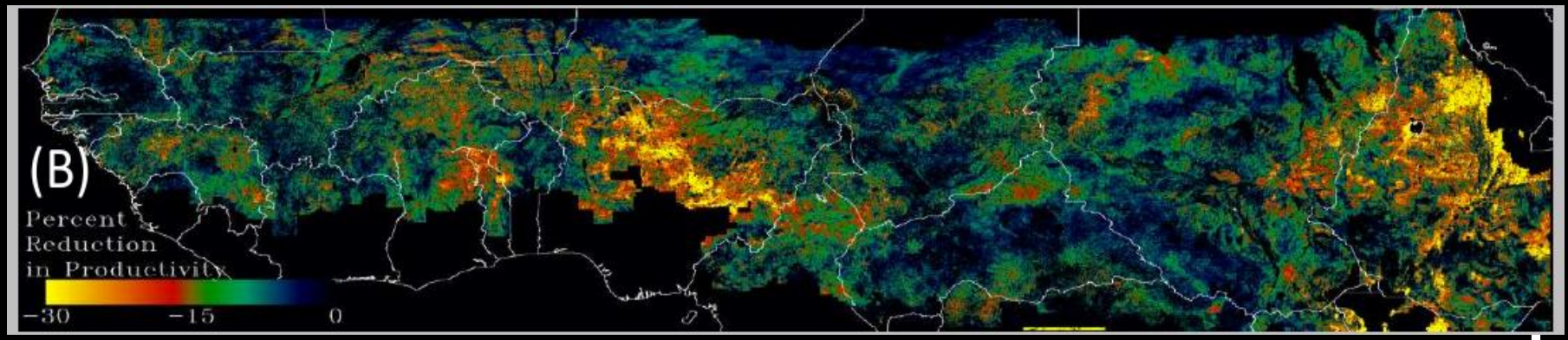
Global climate model predictions of future crop production are integrated with socio-economic information, enabling estimates of future changes in food security for response planning.



*** USAID, see http://www.fews.net/ M. Brown/GSFC**

Soil Degradation Studies





NASA Earth Science

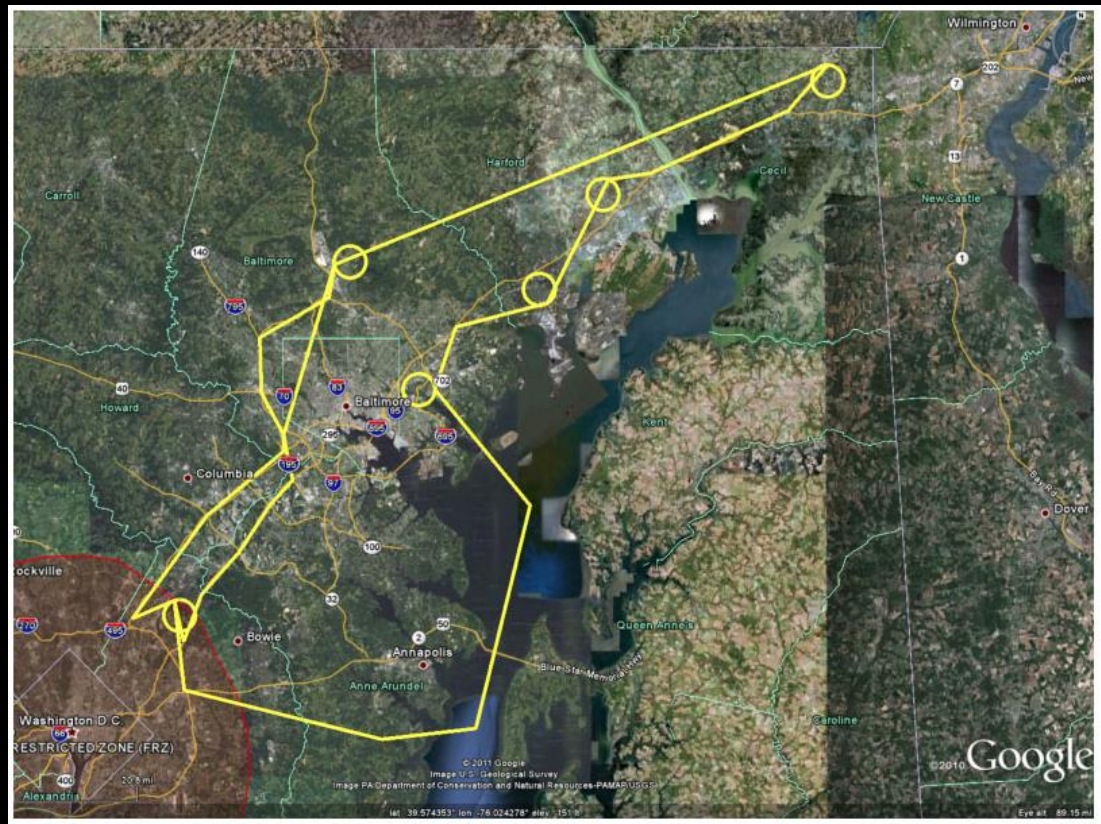
- *Satellite observations* of Earth's global climate provide:
  - Understanding of climate change forcing:
    - > Radiation, Aerosols, Atmospheric chemistry
  - Understanding of climate change impacts:
    - > Cryosphere, Hydrosphere, Ecosystems
- *We meet national needs* for understanding climate change
  - Develop and operate climate-observing satellites
  - Develop and validate climate models
  - Deliver climate data to meet national needs□
- *Climate models and data* support:
  - Agency needs: USGS, DOD, NOAA, EPA, USFS, …
  - Research: climate, weather, biospheric, …
  - Commercial interests: agriculture, fisheries, development, …


Thank You!

Earth Science Division
Field Programs and Instrumentation Development

- **Major Field activities:**
  - **GLoPAC Global Hawk – Paul Newman**
  - **GRIP – Gerry Heymsfield**
  - **Operation Ice Bridge – Lora Koenig, Michael Studinger**
  - **Discover-AQ:**

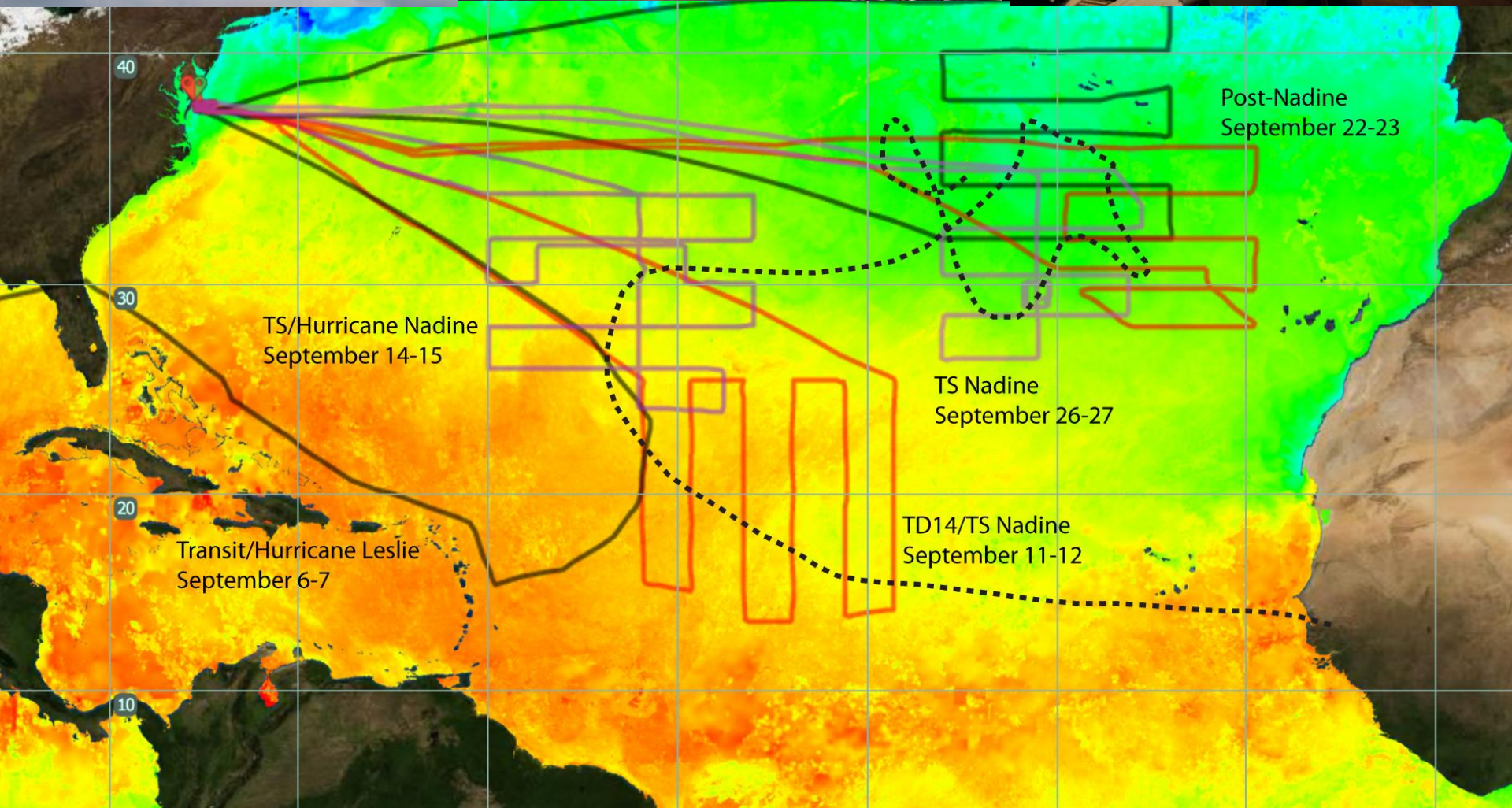
Discover-AQ improves satellite measurements of atmospheric aerosols and pollution:
• using satellite column measurements to diagnose surface conditions
• improved understanding of diurnal variability effects on satellite measurements
• improved representation of small scale features in coarser satellite data sets



Field Programs and Instrumentation Development: Global Hawk as a Research Platform

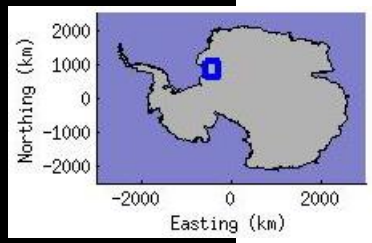
- **Global Hawk Pacific Mission (GloPac):**
  - **NASA GloPac campaign was the first Earth Science mission using the Global Hawk.**
  - **The GloPac measures greenhouse gases, ozone-depleting substances, aerosols, and constituents of air quality in the upper troposphere and lower stratosphere (13º-85º N, almost to Hawaii)**
  - **The GloPac payload: Cloud Physics Lidar (CPL) and Airborne Compact Atmospheric Mapper.**

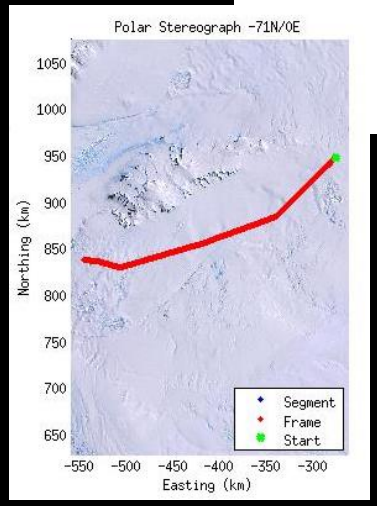
- **Genesis and Rapid Intensification Processes (GRIP) experiment:**
  - **GRIP Hurricane Mission investigated tropical storm formations and intensification into major hurricanes. It was the first ever over-flight by a GH during intensification**
- **Hurricane and Severe Storm Sentinal (HS3)**
  - **The Hurricane and Severe Storm Sentinel (HS3) is a five-year mission specifically targeted to investigate the processes that underlie hurricane formation and intensity change in the Atlantic Ocean basin.**
  - **HS3 is motivated by hypotheses concerning the roles of the large-scale environment, including the Saharan Air Layer, and storm-scale internal processes.**

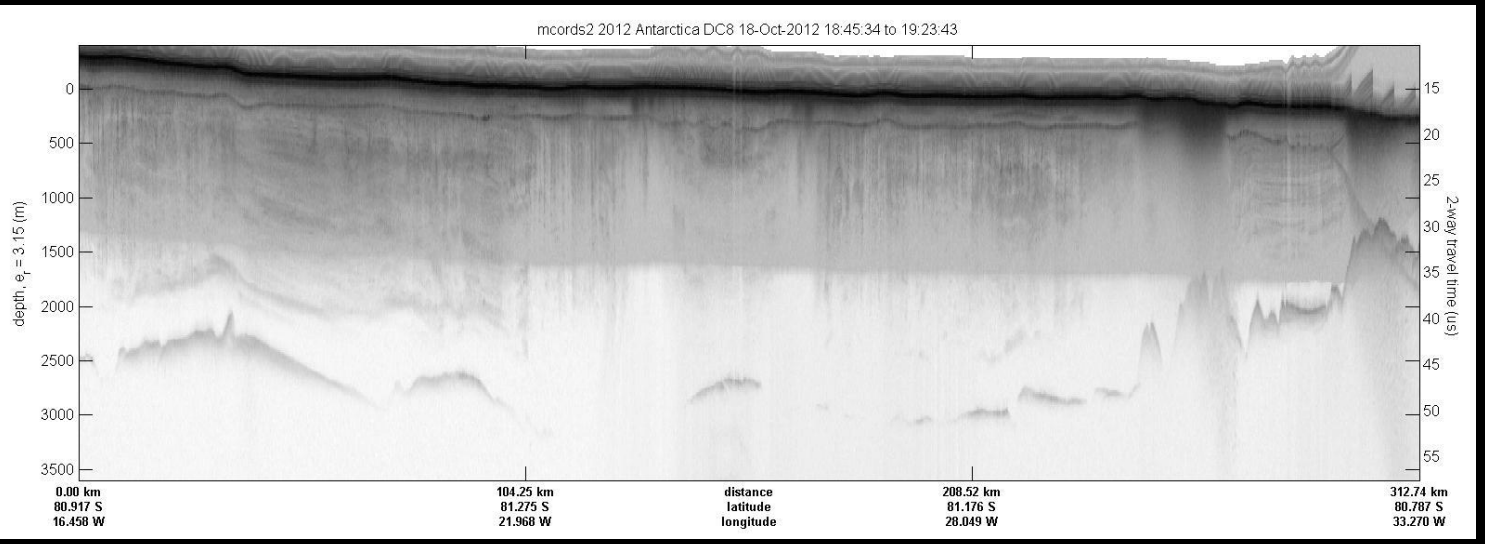

40
30
20
10
Post-Nadine
September 22-23
TS/Hurricane Nadine
September 14-15
TS Nadine
September 26-27
TD14/TS Nadine
September 11-12
Transit/Hurricane Leslie
September 6-7

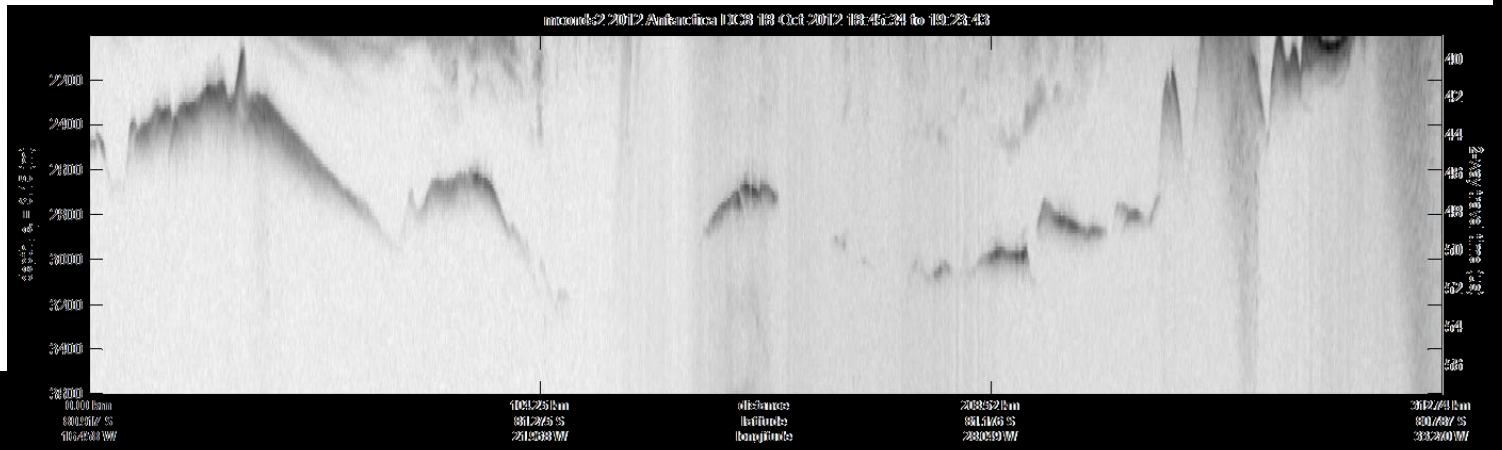
Polar Ice
(Operation IceBridge)

Recovery Glacier Channel

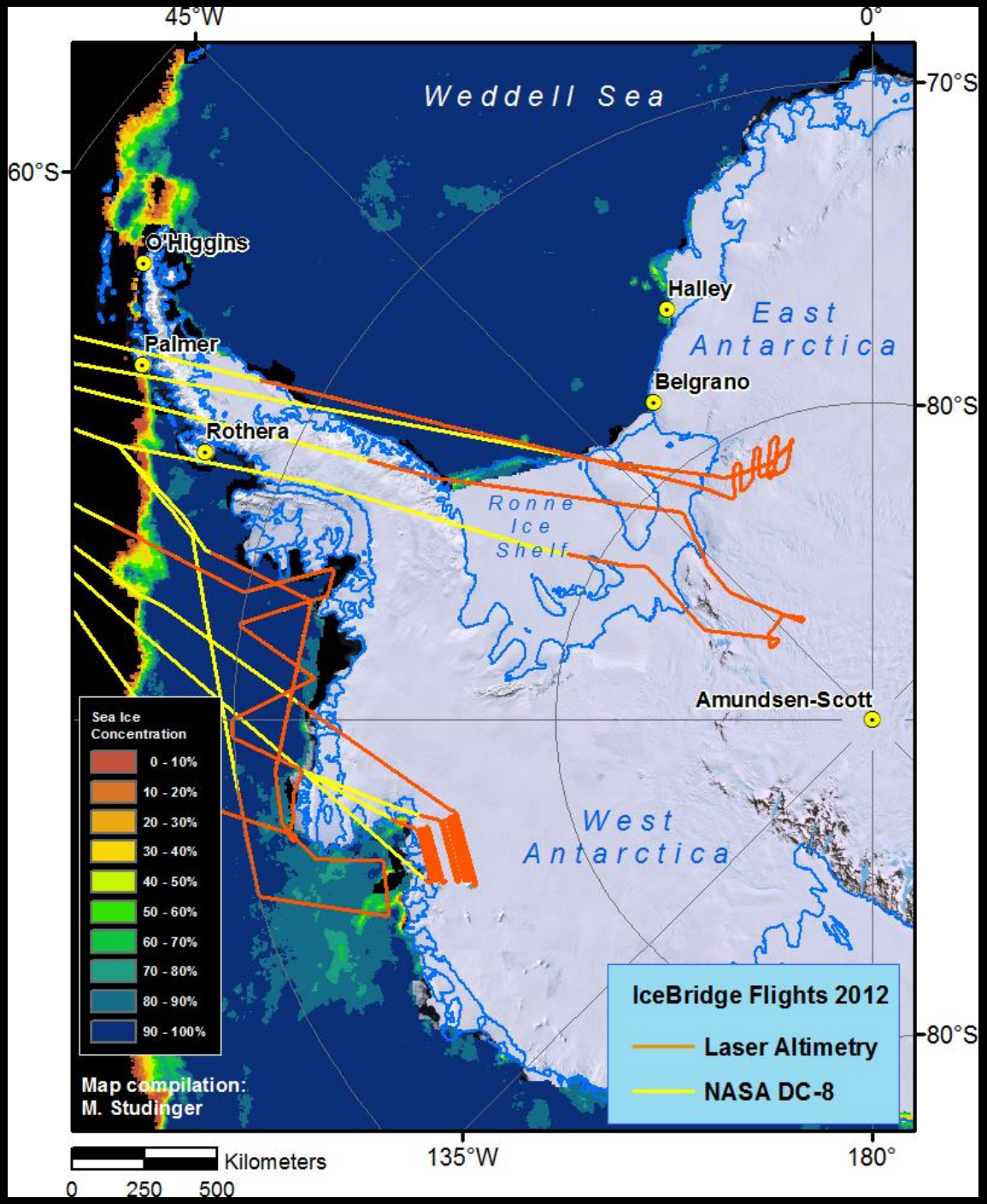








Ice thickness data from CReSIS MCoRDS radar depth sounder provided by CReSIS team.

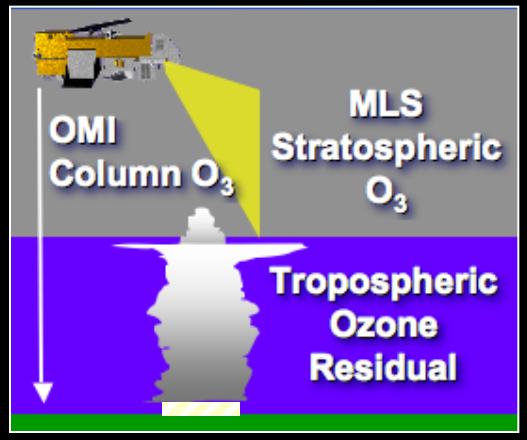


IceBridge Science missions flown so far.

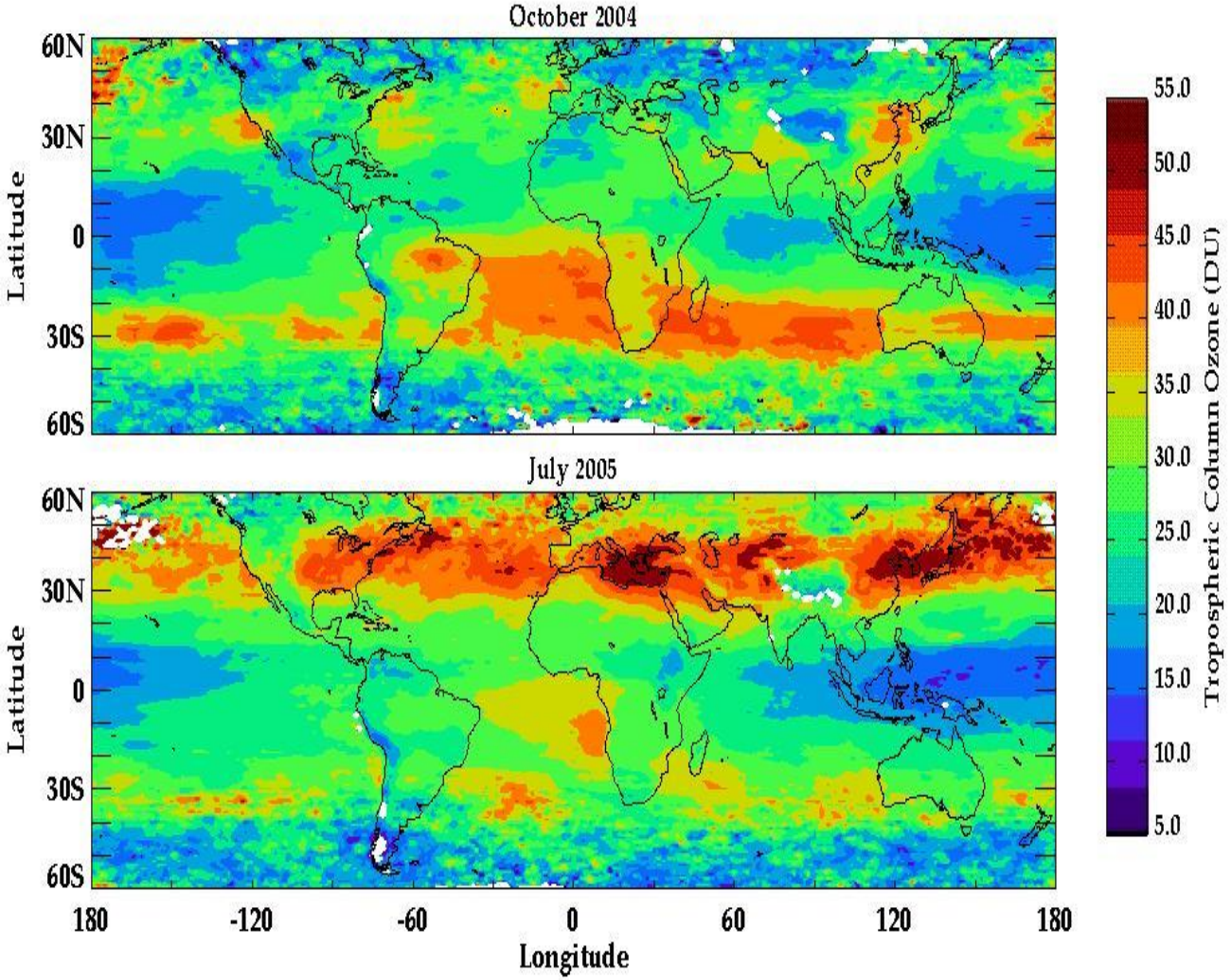
Yellow marks aircraft trajectory.

Red segments indicate preliminary estimate of segments with ATM laser altimetry data.

OMI & MLS*: Global Tropospheric Ozone Residual

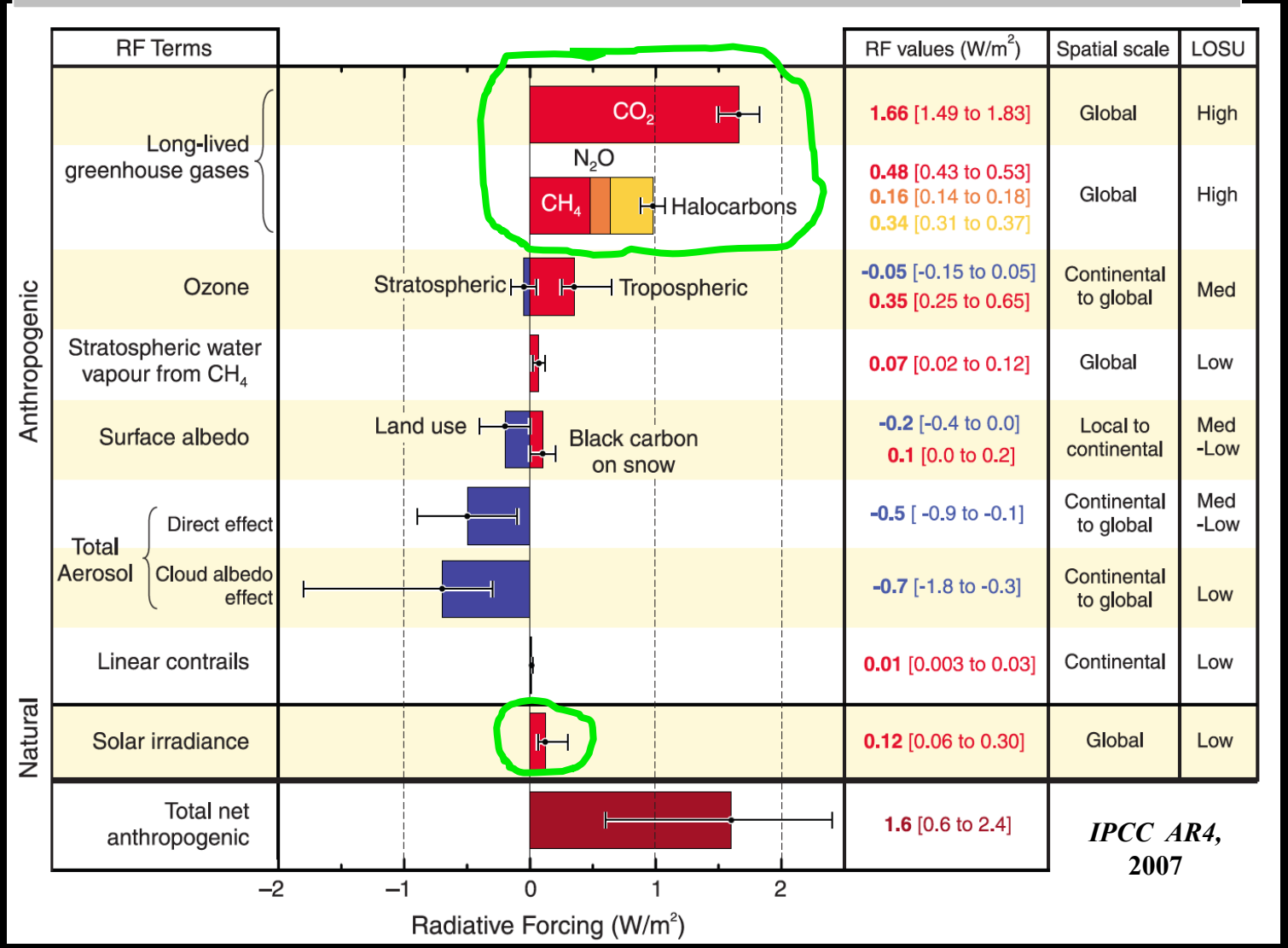


Augmenting TES tropospheric ozone measurements, OMI & MLS can produce a tropospheric residual product by subtracting the MLS stratospheric ozone from OMI column ozone.



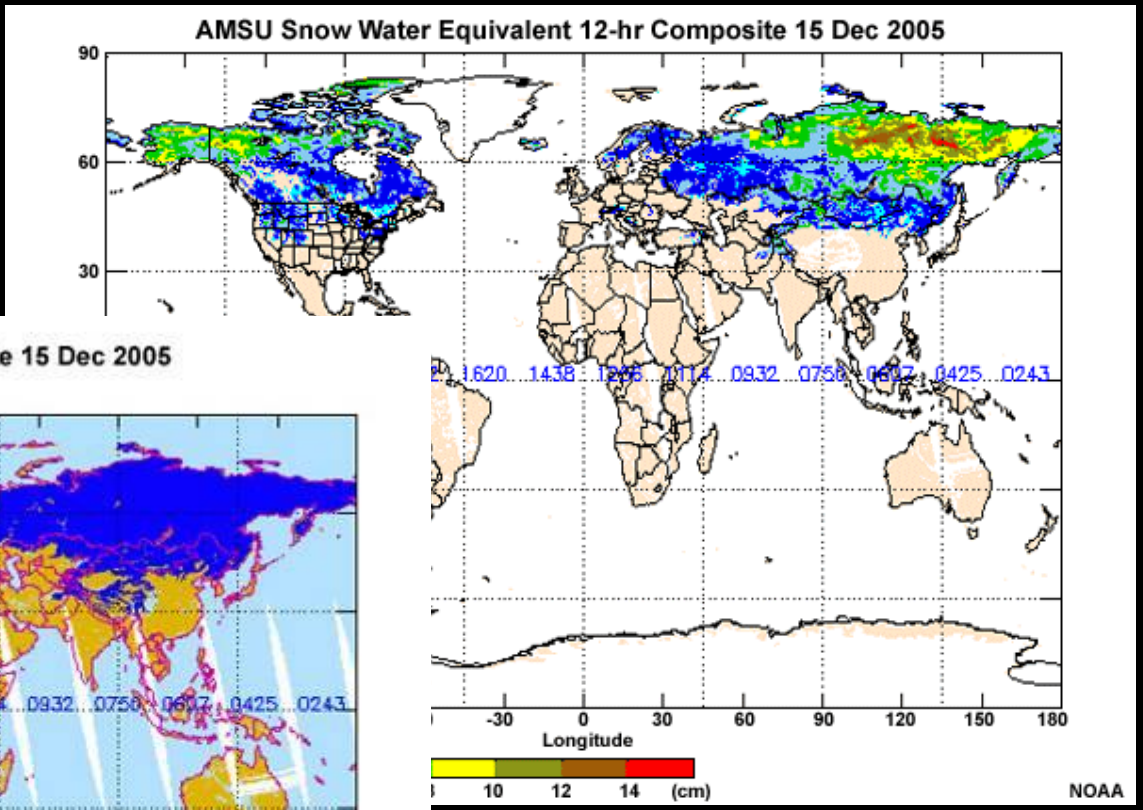
*** Ozone Monitoring Instrument & Microwave Limb Sounder Instruments on the AURA satellite**

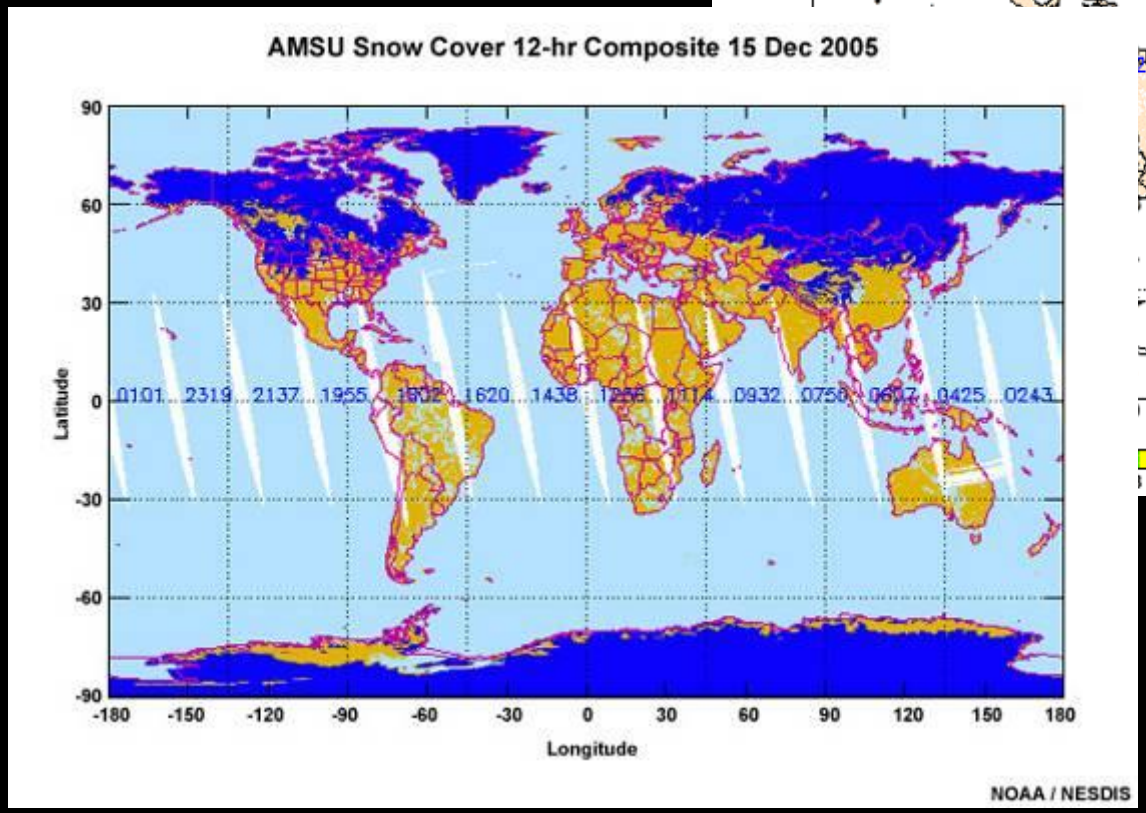
Radiative Forcing Components



IPCC AR4, **2007**

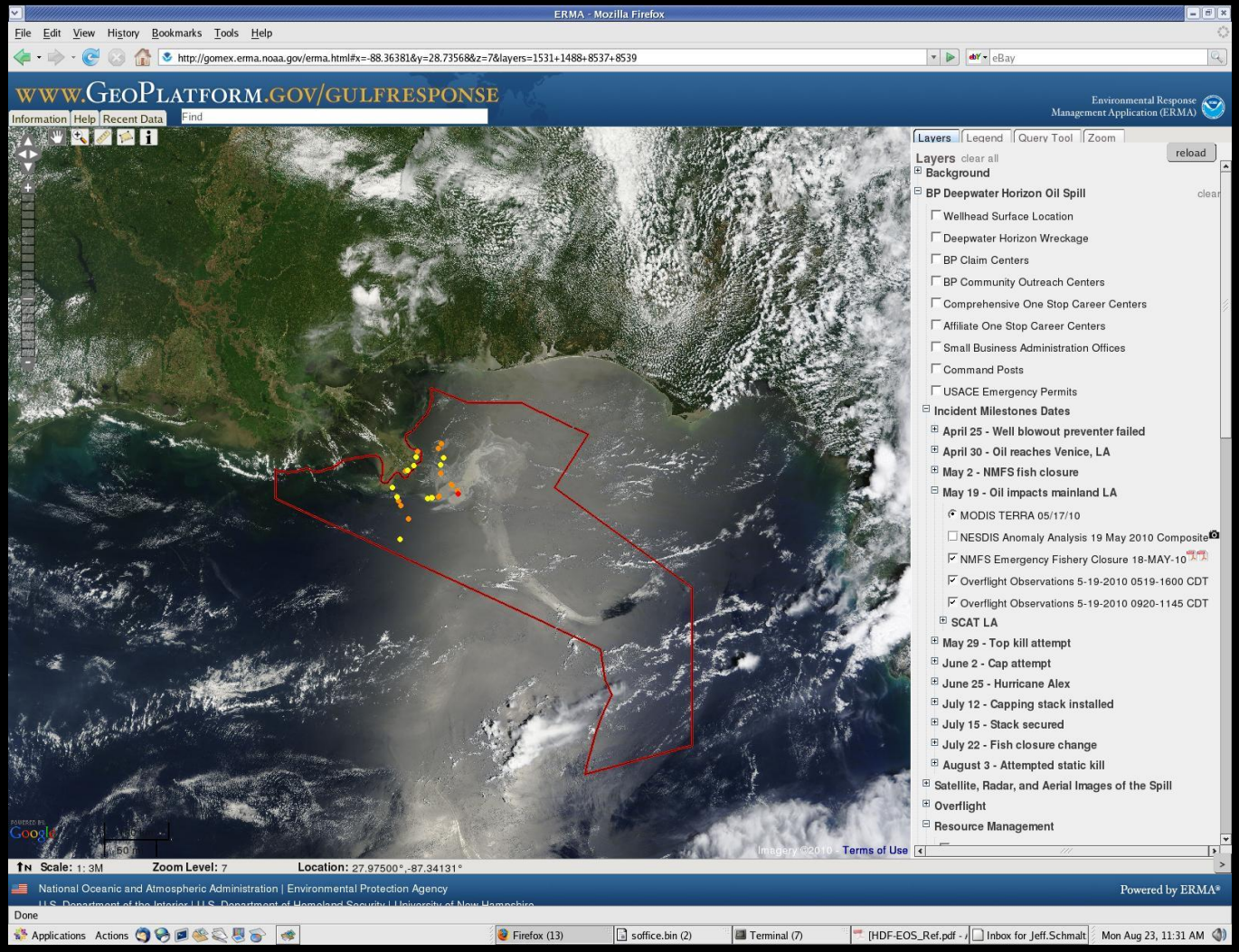
Snow Cover and Water Content





*** Advanced Microwave Sounding Unit Instrument, developed by NASA,flown on NOAA polar orbiter satellites**

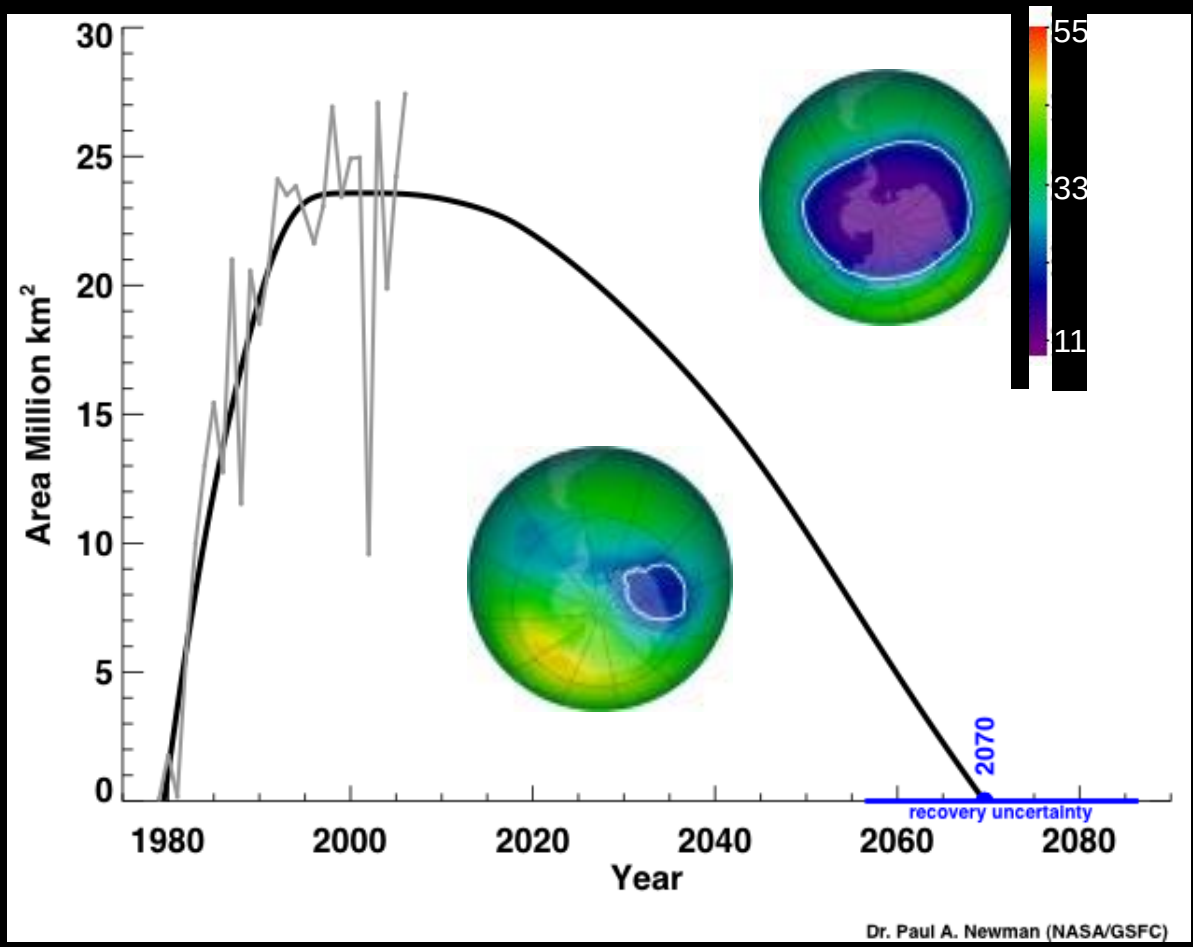
Gulf Oil Spill



MODIS Terra true-color image of the Gulf Oil spill. Other GIS layers displayed include the fishery closure boundary (red outline) and aircraft oil observations (red, yellow, and orange dots).

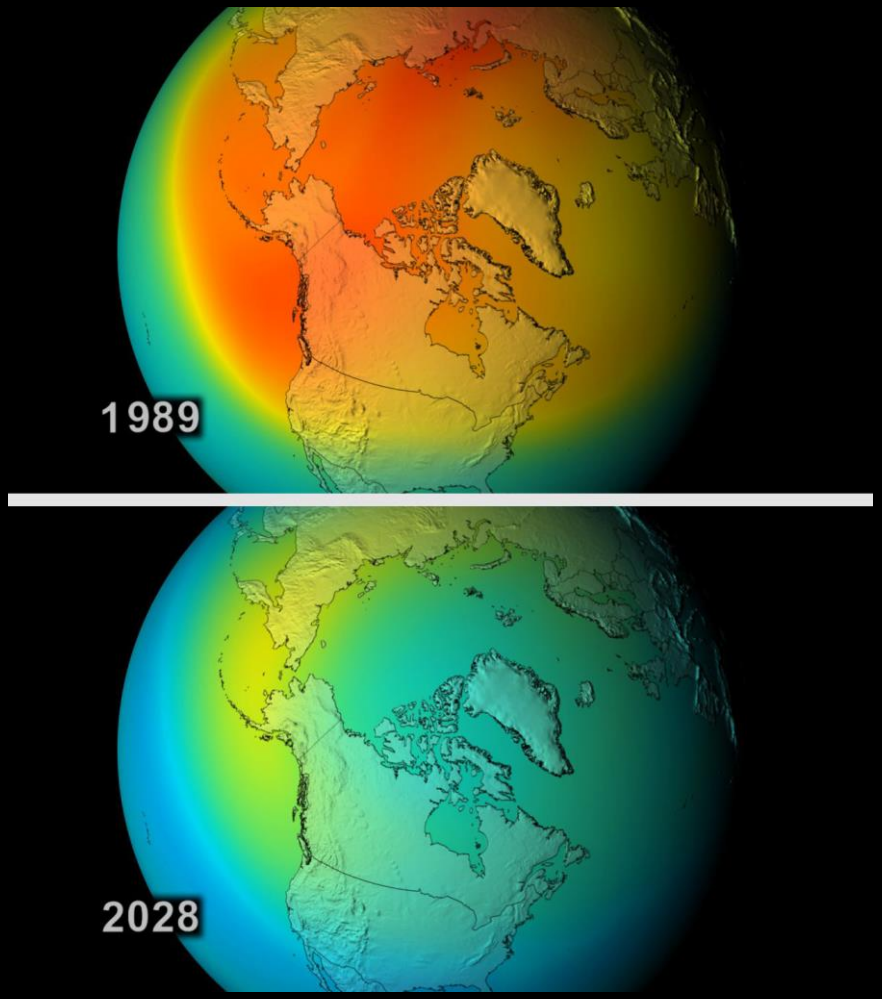
Ozone Hole Recovery

- **Antarctic ozone depletion (the "ozone hole") is caused by human-produced chlorine and bromine gases (CFC's). Ozone screens harmful ultraviolet radiation. Now that CFC's are banned when will the ozone hole recover?**
- **We have developed a parametric model of the ozone hole area that is based upon satellite, ground, and aircraft observations of ozone and chlorine and bromine species.**
- **From this model, we estimate that the ozone hole area will begin to decrease in 2023, and will be fully recovered to 1980's levels by 2070.**
- **Recent occurrences of particularly small (2002) or large (2006) ozone holes are not indicative of a long-term trend.**



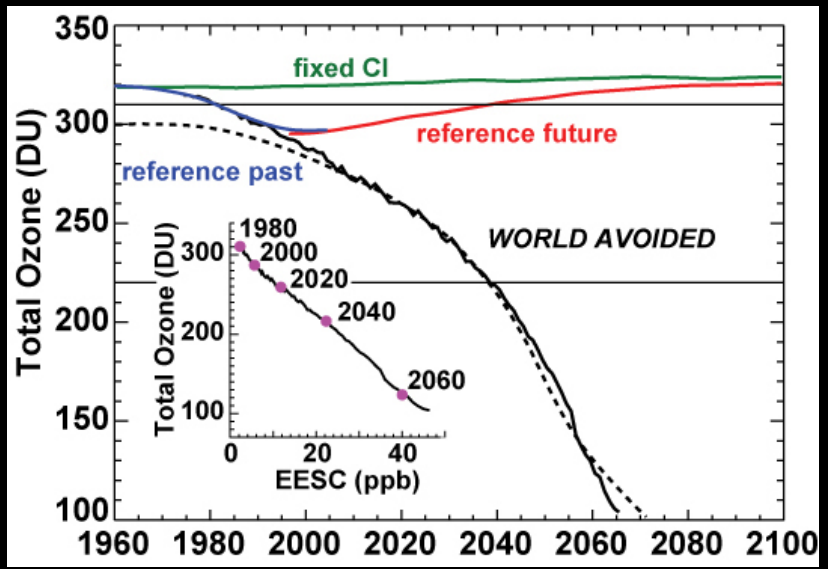
A Disaster Averted

Modeling the ozone layer shows the success of past policy changes:



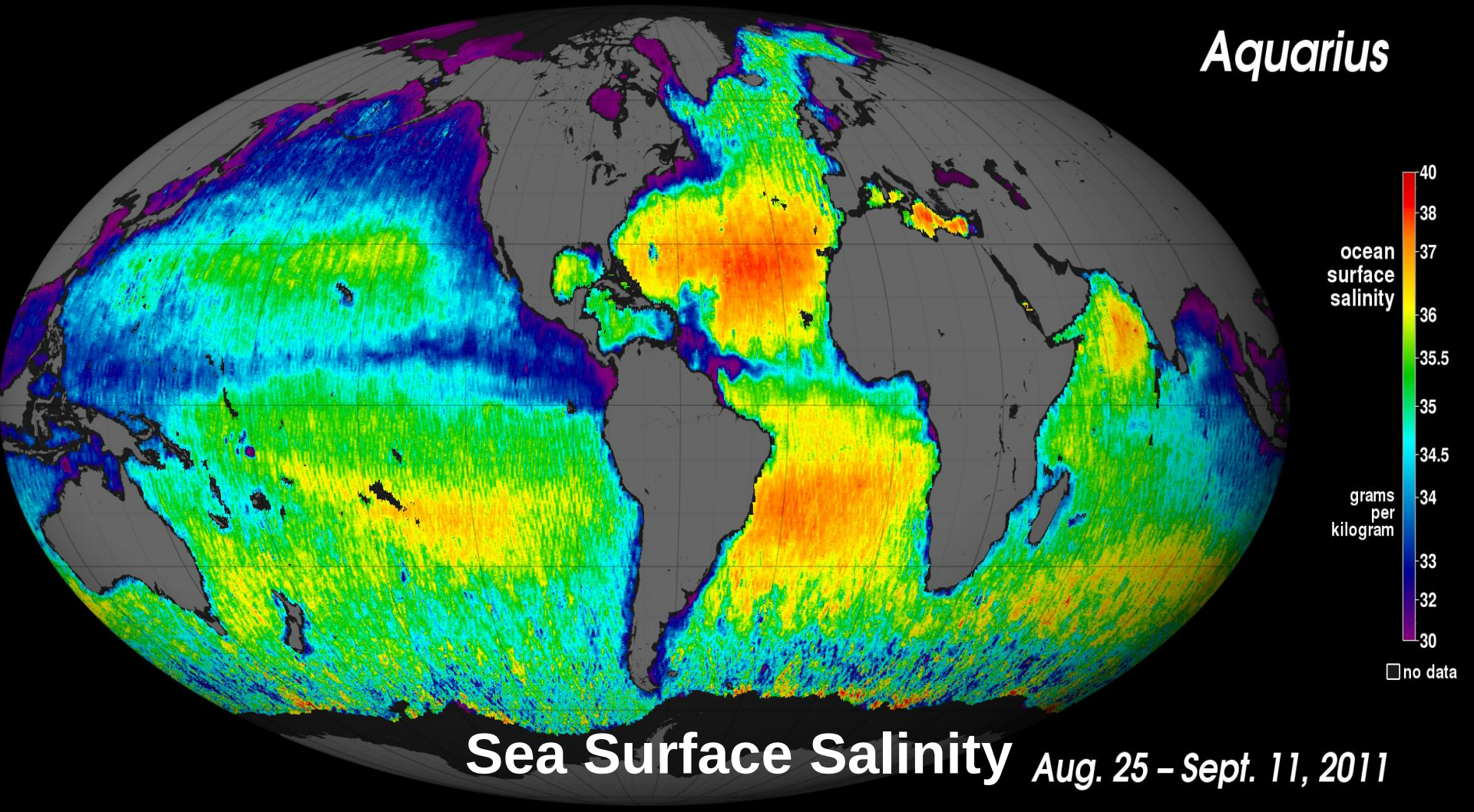
NASA Goddard's Scientific Visualization Studio

Using the Goddard Earth Observing System Chemistry-Climate Model, GSFC scientists showed that a dangerous ozone hole (and a 650% increase in UV radiation) would have spread over the Northern Hemisphere by 2065 if CFC's had not been limited by international treaty in 1987. Paul Newman, et. al.; published in *Atmospheric Chemistry and Physics*



Earth Sciences Division

Research Satellite: Aquarius Ocean **S**alinity Mission



Aquarius Satellite: Launched June 2011

Sea Surface Salinity: salinity and temperature drive ocean circulation